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Data-Driven Evaluation of Background Radiation Safety Using Machine Learning and Statistical Analysis

Muhammad Abid[1], **Muhammad Shahid**[2,*]

[1]Department of Physics and Astronomy, Georgia State University, Atlanta, 30303 GA, United States; abidaminnaeem@gmail.com

[2]Department of Mathematics, North Carolina State University, Raleigh, 27695 NC, United States; shahid1@gsu.edu

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Abstract

The entire globe is radioactive naturally, and humans are constantly exposed to background radiation from cosmic rays and the radioactive materials in their environment. The concentration and effects of background radiation can vary based on geographical location. Measuring background radiation levels is important for assessing potential health impacts. This study presents a comprehensive data analysis to investigate the levels and impact of background radiation levels in Sahiwal, Pakistan, and determine if the levels are safe according to international standards. Radiation counts were measured using a Geiger-Muller counter at several locations in Sahiwal over 40 days. The data was analyzed using normal distribution techniques to calculate the effective absorbed dose of the ionizing radiation in human tissue. The calculated dose was then compared to internationally accepted safe exposure levels. The effective absorbed dose of ionizing radiation in Sahiwal was determined as 0.27 mSv/year, significantly lower than the worldwide average background dose of 2.4 mSv/year. Based on this result and comparisons to international standards, the study concluded that Sahiwal is a safe area in terms of background radiation exposure for human living. However, more comprehensive measurements over longer periods could provide additional insights.

Keywords: Background Radiation, Geiger-Muller Counter, Radiation Dosimetry, Environmental Safety, Statistical Analysis

Corresponding Author:Muhammad Abid

1|Introduction

The Earth's surface and its atmosphere are continually exposed to the ionizing radiation from various natural and artificial sources. This radiation, known as background radiation, is an integral part of our environment. It originates from cosmic radiation, terrestrial radionuclides, and internal sources within the human body. Understanding the levels and effects of background radiation is crucial for assessing potential health risks and implementing appropriate radiation protection measures[1]. Cosmic radiation, one of the primary components of background radiation, is comprised of high-energy particles originating from outer space. These particles include protons, alpha particles, and heavier atomic nuclei that continuously bombard the Earth's atmosphere. The strength of cosmic radiation varies depending on factors such as altitude, latitude, and the Earth's magnetic field. At higher altitudes and higher latitudes, the cosmic radiation levels tend to be more significant.

Terrestrial radionuclides, such as the uranium, thorium, and potassium-40, are naturally present in the Earth's crust and contributing significantly to the background radiation. These radionuclides and their decay products emit alpha, beta, and gamma radiation, which can be detected in soil, rocks, and construction materials[2]. The concentration of these radionuclides varies geographically, leading to different levels of background radiation in different regions. Internal sources of background radiation are caused by the existence of naturally occurring radionuclides within the human body. These radionuclides, such as potassium-40, radium-226, and carbon-14, are ingested through food and water or inhaled from the air. While the radiation doses from these internal sources are generally low, they contribute to the overall background radiation exposure.

The levels of background radiation can be influenced by various factors, including geological formations, building materials used in construction, and human activities. For instance, certain regions with higher concentrations of naturally present radioactive elements in the soil or bedrock may exhibit elevated levels of background radiation [3]. Additionally, the use of specific construction materials, such as granite or certain kinds of concrete, can increase indoor radiation levels. Measuring and monitoring background radiation is essential for evaluating potential health risks and implementing appropriate radiation protection measures. Several techniques and instruments are employed to detect and quantify the different components of background radiation, including Geiger-Müller counters, scintillation detectors, and gamma-ray spectrometers. These measurements provide valuable data for assessing radiation exposure levels and developing strategies to mitigate potential health risks[4].

The effects of background radiation on people's health have been extensively studied, and the scientific community has established guidelines and regulations to ensure radiation protection. While low levels of background radiation are generally considered safe, exposure to elevated levels can potentially increase the risk of certain health issues, such as cancer. Therefore, it is crucial to maintain background radiation levels within acceptable limits and implement appropriate protective measures when necessary. Several studies have been carried out worldwide to assess background radiation levels and their potential impact on human health. These studies have focused on various regions, including areas with naturally occurring high background radiation levels, as well as urban and industrial areas where human activities may contribute to increased radiation levels [5]. The findings from these studies have informed radiation protection policies and guidelines at national and international levels.

In addition to natural sources, human activities can contribute to background radiation levels through the use of nuclear technologies, such as nuclear power plants, medical imaging facilities, and research laboratories. While these activities are subject to strict regulations and safety protocols, it is essential to monitor and mitigate potential radiation exposures to protect both workers and the people in general. The assessment of background radiation levels is not only important for human health but also for environmental monitoring and protection. Elevated levels of background radiation can potentially impact various ecosystems, affecting plant and animal life [6]. Understanding the distribution and sources of background radiation can help develop strategies for environmental conservation and sustainable development.

International organizations, such as the International Atomic Energy Agency (IAEA) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), play a crucial role in coordinating research efforts, establishing guidelines, and promoting radiation protection measures globally [7]. These organizations collaborate with national authorities and research institutions to facilitate the exchange of information and best practices in managing background radiation levels. Technological advancements in radiation detection and measurement techniques have contributed significantly to our understanding of background radiation. Improved

instrumentation and computational methods have enabled more accurate and detailed assessments of radiation levels, sources, and distributions. These advancements have also facilitated the development of effective shielding materials and techniques for mitigating radiation exposure.

The study of background radiation is not limited to terrestrial environments; it also extends to extraterrestrial environments, such as space exploration missions. Understanding the background radiation levels in space is crucial for ensuring the safety of astronauts and the proper functioning of sensitive equipment. This knowledge has been instrumental in the design of spacecraft and radiation shielding systems for space missions. In recent years, the integration of background radiation data with geographic information systems (GIS) and spatial analysis techniques has provided valuable insights into the spatial distribution and patterns of radiation levels [8]. These tools allow researchers to visualize and analyze radiation data in relation to various environmental and geological factors, facilitating more informed decision-making processes.

While background radiation is a natural phenomenon, human activities can inadvertently alter its levels through practices such as mining, nuclear accidents, and improper waste disposal. Ongoing research efforts focus on identifying and mitigating the potential impacts of these activities, as well as developing strategies for remediation and environmental restoration in affected areas. The public's perception and understanding of background radiation play a crucial role in shaping attitudes and policies related to radiation protection. Effective communication and education initiatives are essential to promote awareness and dispel misconceptions about the risks associated with background radiation. This can foster informed decision-making and encourage responsible practices in radiation management. Neutrons and cosmic rays are some of the sources of ionizing radiation. Nuclear reactors produce neutron radiation. Cosmic rays emanate from stars in space and form part of the worldwide background radiation we are all exposed to every day. Natural sources account for 85% of a person's annual dose of radiation, these include radon, which is a gas that comes out of rocks forming the earth's crust; food/drinking water; cosmic radiation; exposure from buildings and soil[9]. On the other hand, 15 percent is artificial and mainly arises from exposures for medical purposes. Lastly, one percent comes from nuclear industry-related activities shown in Fig-1.

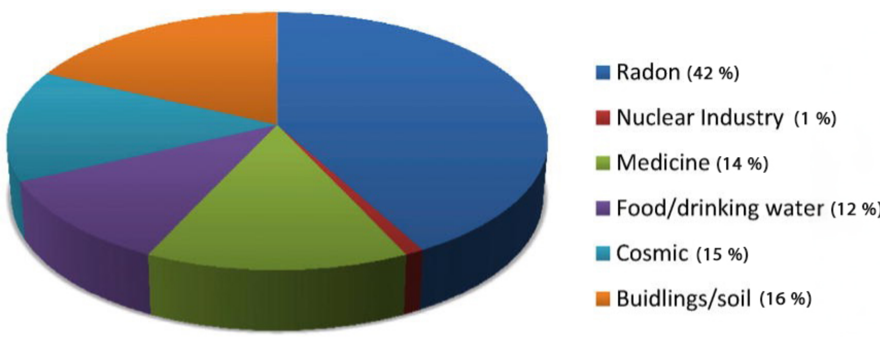

Figure 1. Sources of background radiation.

A Geiger counter (Geiger-Muller) is an instrument used for the measurement and detection of radiation, namely alpha, beta, and gamma radiation. It detects the ionizing radiation such as alpha particles, beta particles, and gamma rays by the ionization effect created in a Geiger–Muller (GM) tube, which gives the instrument was named. Used extensively as a hand-held radiation survey tool, it is likely one of the most recognized radiation detection equipment anywhere in the world. The original detecting mechanism was discovered at the Cavendish laboratory in 1908; nevertheless, it was not until 1928 with the development of the GM tube that the GM counter became a practical instrument. After that, it has been extremely popular because of its rugged sensing element and fairly low cost. However, there are limited high radiation rates measuring and energy of incident radiation.

In its operation principle, it is basically composed of a pair of electrodes surrounded by a gas. There is a high voltage across the electrodes. The gases used are usually Argon or Helium. Radiation entering the tube can ionize this gas. The ions (and electrons) will then be drawn to the electrodes where an electric current is initiated. The current pulses are then passed through a scalar, and thus one gets a count each time radiation causes ionization of the gas (shown in Fig-2).

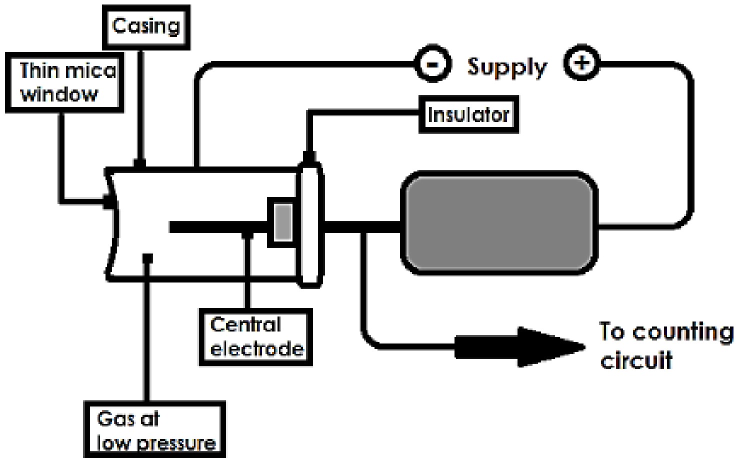

FIGURE 2. Internal view of G.M Tube.

The system comprises two components: the tube and the second part (counter + power supply). Typically the GM tube is cylindrical in shape, with a centrally located wire. The second part (counter + power supply) has voltage controls as well as timer controls. In this way, when an ionizing radiation/particle such as an alpha, beta, or gamma particle enters in the tube, it causes ionization of some gas molecules in the tube. The atoms from which these ions were formed become charged positively. This voltage is responsible for creating a very high electric field within the tube. Ions move toward electrodes of opposite charge to restore charge neutrality; electrons flow to where a positive charge has been lost and negative ions go towards a positive pole. This results in a pulse of current in the wires that connect the electrodes, which is then simply tallied. Once the pulse has been counted, the charged ions are neutralized and ready for another pulse to be recorded by the Geiger counter. (Full schematic for the G.M. counter is shown in Fig-3 and details are shown in Table-1)

In order for the GM counter tube to be quickly restored from the state formerly described, a gas is introduced into the tube. For the GM counter to function in the correct manner, there must be an electrical voltage between the electrodes. When the voltage is excessively low, then the electric field in the tube is not sufficient for initiating a current pulse and when the voltage is excessively high the tube will get discharged continuously and the tube gets damaged. Often the manufacturer recommends the appropriate voltage to use in the particular tube. Thicker tubes need more voltage to generate the required electric fields within the tube. Firstly, we will perform an experiment that will help us identify the optimum operating voltage. Then, we will introduce a radioactive isotope in front of the GM tube. After that, we will apply a gradual change in the voltage across the tube while observing the counting rate.

Recent advancements in materials science have led to the development of innovative radiation shielding materials and techniques [10]. These include novel composite materials, nanotechnology-based solutions, and advanced shielding designs. Such developments can potentially enhance radiation protection capabilities in a variety of applications, including nuclear facilities, medical imaging (MI), and the space exploration. The study of background radiation is a multidisciplinary endeavor, involving contributions from fields such as physics, geology, environmental science, biology, and engineering [11]. Collaborative efforts among researchers from different disciplines are essential for achieving a comprehensive understanding of background radiation and its impacts. Such collaborations facilitate the integration of diverse perspectives and expertise, leading to more holistic solutions.

In this PSoC design, the high voltage necessary for biasing the GM counter is created by using a pulse transformer controlled by a pulse width modulator signal. This regulation is done through a closed-loop control of the duty cycle of the switching signal. The feedback loop includes a sensing network, an integrator, a relaxation saw-tooth oscillator, plus a comparator. With regard to the implementation of the PWMs duty cycle control in this design, the particular PSoC features a general internal switched capacitor (SC) user module that is known as the ASC

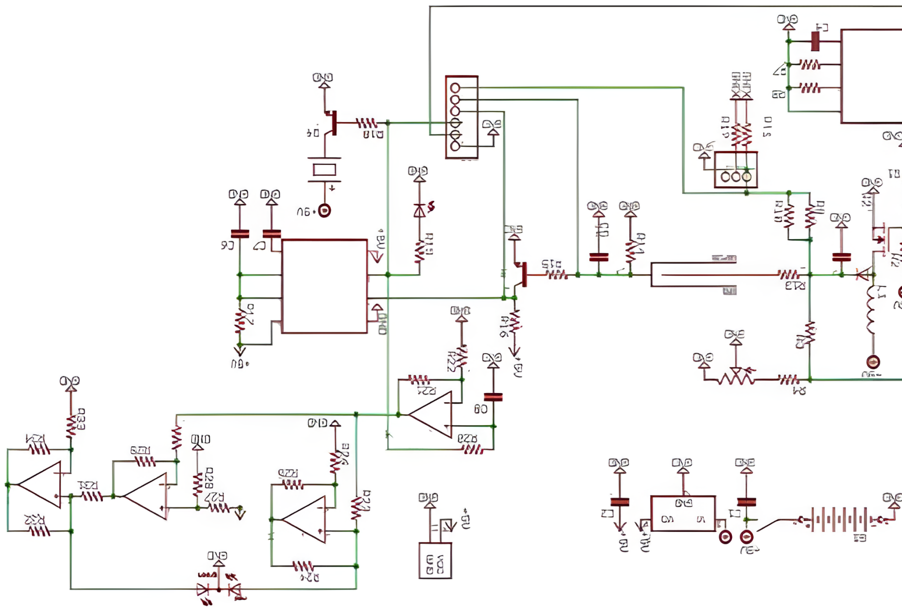

Figure 3. Full Schematic for G.M. Counter.

Table 1. Value of resistance used in G.M Counting circuit

No. of Resistance	Value of Resistance	No. of Resistance	Value of Resistance
R_1	10 kΩ	R_{18}	1 kΩ
R_2	10 kΩ	R_{19}	75 kΩ
R_3	10 MΩ	R_{20}	100 kΩ
R_4	22 kΩ	R_{21}	36 kΩ
R_5	20 kΩ	R_{22}	2.4 kΩ
R_6	4.7 kΩ	R_{23}	1 kΩ
R_7	4.7 MΩ	R_{24}	1 kΩ
R_8	6.8 MΩ	R_{25}	1 kΩ
R_9	1 GΩ	R_{26}	1 kΩ
R_{10}	1 GΩ	R_{27}	1 kΩ
R_{11}	1 MΩ	R_{28}	1 kΩ
R_{12}	1.1 MΩ	R_{29}	1 kΩ
R_{13}	5.1 MΩ	R_{30}	1 kΩ
R_{14}	5.1 kΩ	R_{31}	1 kΩ
R_{15}	10 kΩ	R_{32}	1 kΩ
R_{16}	1 kΩ	R_{33}	1 kΩ
R_{17}	6.2 kΩ	R_{34}	1 kΩ

and ASD blocks. It is important to describe the high voltage generation in detail and based on the information gathered above.

In addition to human health and environmental considerations, background radiation research has implications for various industries, including mining, construction, and agriculture [12]. Understanding the radiation levels associated with specific materials and processes can inform best practices, safety protocols, and regulatory frameworks within these industries. The assessment of background radiation levels is not only relevant for the present but also has implications for future generations. Long-term monitoring and predictive modeling efforts aim to understand the potential changes in background radiation levels due to factors such as climate change,

geological processes, and human activities [13]. This knowledge can inform sustainable development strategies and ensure the protection of future generations.

Advances in computational modeling and simulations have significantly enhanced our ability to predict and understand the behavior of background radiation in different scenarios. These tools allow researchers to explore various "what-if" scenarios, investigate the potential impacts of various factors, and develop mitigation strategies accordingly. The study of background radiation is not limited to the Earth's surface; it also extends to undersea environments, where radionuclides can accumulate in marine sediments and organisms. Understanding the distribution and behavior of background radiation in these environments is crucial for assessing potential impacts on marine ecosystems and ensuring the safety of seafood consumption.

Emerging technologies, such as unmanned aerial vehicles (UAVs) and remote sensing techniques, are increasingly being utilized in background radiation monitoring and mapping efforts. These technologies offer new opportunities for data collection in remote or inaccessible areas, as well as for large-scale spatial mapping of radiation levels [14]. The integration of background radiation data with other environmental and health data sets has opened up new avenues for research and analysis. By combining radiation data with factors such as air quality, water quality, and epidemiological data, researchers can investigate potential correlations and develop more comprehensive risk assessment models.

2|Literature Survey

In WW2, the United States used atomic bombs for the first time and bombed two cities in Japan with the same. Despite the fact that these bombs can be referred to as relatively weak in comparison with contemporary nuclear weapons, they inflict considerable harm upon the cities of Nagasaki and Hiroshima [15]. The energy and destructive power of a nuclear bomb are released via Nuclear Fission, which involves bombarding atoms (oftentimes Uranium or Plutonium). These split halves are called fission products and are the remnants of a nuclear chain reaction. These waste products are highly radioactive for example they can cause death within several hours of intake or slightly increase lifetime cancer risks. Fortunately, the more radioactively energetic the nuclear soup, the shorter it hangs around. This means that the very deadly type will only be radioactive for a very few hours to a couple of weeks. The less active kind can last for years. Some elements, such as Plutonium, can exist for more than 25,000 years or even indefinitely[16]. It is true that this kind of radiation cannot actually kill you right away, but long-term exposure to it definitely increases your chances of developing cancer and might lead to other diseases.

2.1|Radiation Risk

Prompt radiation burst the radiation threats that were in view for the people occupying the Japanese cities were two. The greatest danger lies in what is referred to as prompt radiation. This is the high-energy neutrons and gamma rays that are produced right at the moment when the nuclear device is detonated. This radiation is very short-lived and its effect is only felt immediately after the bright flash of light experienced during a nuclear blast. To be killed by this often referred to as an extremely penetrating kind of radiation, a person must be within 2 miles away from the point of bombing. However, at this distance, they may die due to falling debris, collapsed buildings, or by the impact of the explosion itself. From this graph, we can regard that the new instant radiation death rate costs 20% of Nagasaki & Hiroshima death [17].

The world is innately ill-lumined with radiation and about 82% of the radiation doses ingested by humans and which are uncontrollable, originate from background radiation from cosmic rays, terrestrial radiation, and exposure from inhaled or taken in radiation sources[18]. Recently, several much international researchers have been performed and calculated different values different resulting from background-radiation affecting people's health. Primordial gamma radiation mainly from Th^{232} and U^{238}[19]. This is so because their concentrations in the soil, sand, and the rocks vary depending on the geology of every region of the world. They generally comprise of Terrestrial origin with most of the materials containing radioactive elements that existed when Earth was formed. Furthermore, there are certain springs and quarries that escalate the dosage rate of the background radiation in some of the identified HLBRs. It was also found that the kind of construction material used in houses influences the dose rate of background radiation.

Since it is estimated that the approximately half was exposed to natural sources, most cancer patients suffer from respiratory and gastrointestinal disease, and the largest portion of radon in human body is inhaled and ingested in drinking water. Once radon in water supplies gets delivered to the consumers it can cause exposure to humans by inhaling and by directly consuming the water. That is why radon in water moves into the atmosphere when it rains, when people flush toilets, wash dishes, and wash clothes. Since they remain suspended in the air for long they settle on the lungs and release emissions containing radiation which are known to cause lung cancer. Through the ingestion of food, the radon reaches other tissues of the body thereby irradiating the internal organs. Swallowing radon is also reported to cause stomach cancer in people[20]. Besides in use of soils for building materials, they influence the exposure of the population by using food containing radionuclide that enters the food chain from deeper soil layers which pollutes the groundwater. Individuals can be exposed to radiation through various pathways, whether from natural sources or human-made ones. As depicted in Fig-4, exposure can occur through the following process.

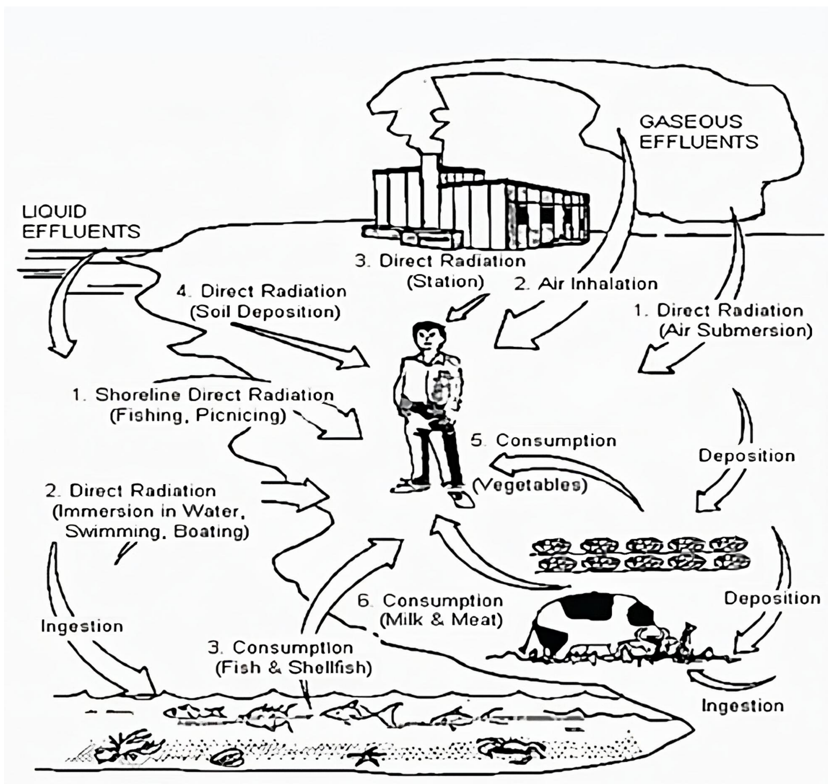

FIGURE 4. Pathways of radiation exposure resulting from effluent releases from nuclear plants and fuel-cycle facilities.[21]

Cosmic rays arise from the stars, sun, dead stars (like neutron stars), quasars, and hot intergalactic and galactic plasma. Like, it includes x-rays, gamma rays, or maybe particles like electrons, protons, mesons, neutrons, and hyperons, etc. The kinetic energy of the particles (individually) is distributed over a wide range starting from a few electron volts (eV) up to approximately 1020 eV [22]. The cosmic radiation also decelerates the moment the particles start penetrating the more dense layers of the atmosphere. The soft components of energy radiation such as soft X-rays cannot penetrate through the atmosphere as well as the force of earth's magnetic field.

In general, height and latitude have a minor influence on the natural dosage rates from cosmic rays. The Earth's magnetic field, which has the tendency to push ions away from the equator and toward the poles, and the charged particle composition of primary cosmic rays are the two factors responsible for the latitude effect. Neutrons in the environment can form radioactive isotopes like C^{14} and H^3. The thickness amount of the atmosphere is equivalent to around 10 meters of water or 4 meters of concrete. It plateaus at a somewhat higher height

of 15 km & 60° magnetic latitude, reaching a maximum of 30 mSv each year[23]. Cosmic radiation rises with magnetic latitude, particularly at higher altitudes.

An Iranian assessment of the natural radioactivity in buildings looked at five typical building materials: gypsum, cement, gravel, and bricks. This assessment stated that the cement specimens had the maximum amount of the mean Ra^{226} and Th^{232} congregation, while the lowest value for the average congregation of these two radionuclides was discovered in the gypsum samples. Brick and gypsum samples had the highest and lowest K^{40} mean concentration values, respectively. The danger index values were determined to be lower than expected. As a result, buildings made of these materials are thought to be safe for their occupants [24]. These survey results are congruent with those of previous assessments conducted in other parts of the world.

Several surveys have been conducted in recent decades to determine the concentrations of indoor radionuclides in nations such as India and Canada. Several research have been conducted in countries including Vietnam and Turkey. Vietnam's estimated outdoor and indoor yearly effective doses to the population were discovered to be higher than those observed elsewhere in the world. The results revealed that the radium (Ra) equivalent activity and external danger index of the Vietnam soil surface were less than the respective permissible limits of 370 Bq/kg. As a result, the soil used in construction in Vietnam is safe for humans. During another investigation, the natural gamma radiation levels of soil specimens from Turkey's Samsun city center were estimated. The computed external hazard index indicated that the radiation hazard in Samsun was minimal.

A study looked on the radiology of Slovenian natural and mineral drinking waters. During the survey, various types of water were collected for three different age groups of the community. The median effective dosage for all radionuclides studied was significantly lower than the recommended threshold of $100\mu Sv/year$. The results suggest that the children are the most heavily exposed, with the largest absolute dose. It is vital to note that the contribution of each individual radionuclide to total dosages varies across water kinds, genres, and age groups. The Human body has the concentration of activity of potassium K^{40}, tritium H^3, carbon C^{14}, Ra^{226} and polonium Po^{210}, is $63, 133, 66, 2.7 \times 10^{-5}$ and $2.0 \times 10^{-4} Bq/kg$, respectively[25].

2.2|Radioactivity in buildings

Understanding how much radiation people are exposed to from building materials is crucial, especially since we spend about 80% of our lives indoors. Most building materials come from rock and soil, which naturally contain radioactive elements like those from the uranium-238 and thorium-232 decay series, as well as the potassium-40. Scientists have measured the levels of these natural radionuclides in construction materials across different regions, including Australia, Bangladesh, Pakistan, Tanzania, Eastern Europe, China, Syria, Egypt, Cyprus, and Kuwait[26].

Given the significance of this investigation, a survey was conducted within the Portland cement industry. The findings revealed that all the measurements taken were consistent with global data given by the UNSCEAR[27]. In Turkey, an investigation focused on the natural radioactivity levels in granites used for construction found that the high levels of activity were primarily due to the presence of large amounts of orthoclase and radiogenic accessory minerals in this country.

A study in Iran looked into natural radioactivity levels in five commonly used construction elements: gypsum, cement, cement blocks, gravel, and brick. The findings revealed that cement had the highest average concentrations of radium-226 and thorium-232, while gypsum had the lowest. For potassium-40, brick samples had the highest mean concentration, and gypsum had the lowest[28]. The radium equivalent activities for all materials were below the safe limit of 370 Bq/kg, and the hazard indexes were also within safe levels. This means that buildings made from these materials are considered safe for residents. These findings align with similar studies conducted in various countries, including Canada and India, over the past few decades.

A survey of the public elementary schools in Canada found that students and staff were exposed to an average radon concentration of 56 Bq/m^3, which is significantly lower than the Federal guideline level of 200 Bq/m^3. In a study from southwestern Punjab, India, the concentrations of radon-222 in homes ranged from 21 Bq/m^3 to 79 Bq/m^3, with an average of 45 Bq/m^3. Moreover, another study in and around Bangalore, India, measured radon-222 and radon-220 levels in 200 different types of dwellings across 10 locations. The results indicated that

radon-222 levels were within the global average concentration of 40 Bq/m^3, posing no significant radiological risk to residents[29]. However, radon-220 levels were higher than the worldwide average of 10 Bq/m^3.

The natural terrestrial background radiation at any location can fluctuate by several millirads within any given quarter of the year due to factors like changes in rainfall (which affects soil moisture), snow cover, and radon levels. Fig-5 shows the daily variations in radiation exposure rates recorded at a site in New Jersey in 1979.

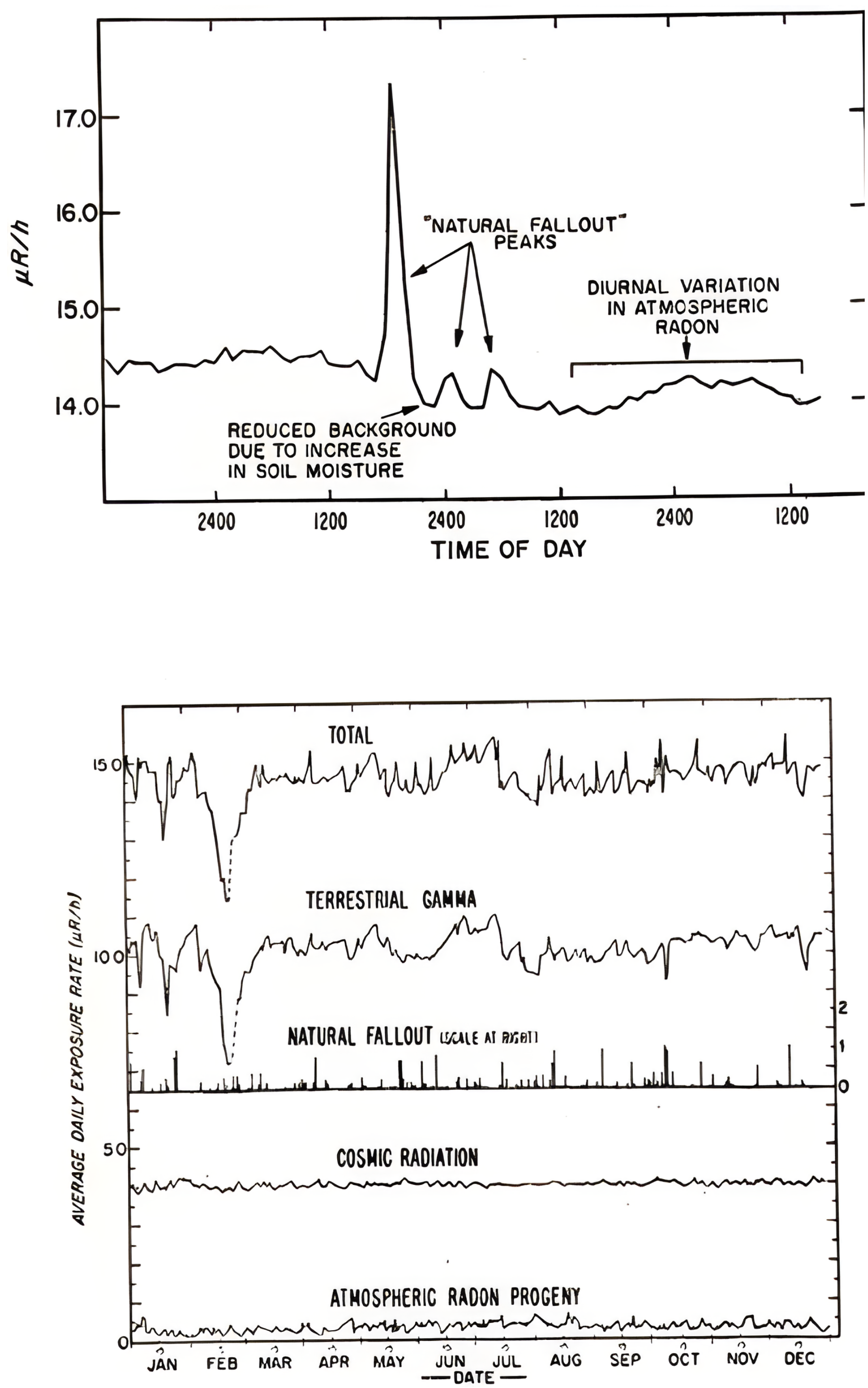

FIGURE 5. Daily fluctuations in background radiation levels at a site in New Jersey.[30]

Humans are constantly exposed to the background radiation from radioactive nuclei found in the atmosphere, rock, soil, water, and construction materials. The level of this radiation varies depending on factors like altitude, the amount of radioactive nuclei in the soil, and the geographic conditions of each place. Radioactivity is naturally present in various environments, including soil, rocks, beach sand, river sediments, oceans, and even in construction materials and dwellings[31]. The concentration of radioactive isotopes in soil serves as an indicator of environmental radioactive buildup that impacts humans, animals, and plants. These isotopes often have exceptionally long half-lives, lasting hundreds of millions of years. Additionally, the presence of radionuclides like thorium and uranium in a region's soil can alter the background radiation dose rate.

2.3|Radioactivity in Food

Trace levels of alpha-emitting radionuclides from the thorium, uranium, and actinium decay series are commonly found in food, water, and air. Radon gas, particularly Rn^{222}, and to a lesser extent Rn^{220} and Rn^{219}, can infiltrate the food supply[32]. This infiltration occurs as radon from the soil and water, along with its decay products, settles on agricultural fields and the vegetation growing there. Since these radioactive elements enter the food chain and can impact human health, several studies have been conducted to measure the concentrations of these elements in food.

A survey was conducted to examine the radiological properties of natural and mineral drinking waters in Slovenia. In this study, different types of water were collected for analysis across three distinct age groups within the population. The findings indicated that all median committed effective doses from the radionuclides studied were significantly lower than the recommended limit of $100\mu Sv/year$[33]. The findings also revealed that children received the highest absolute dose, making them the most exposed group. Notably, the contribution of every specific radionuclide to the total dose varies depending on the type of water, the specific water sample, and the age group being considered.

In the human body, the activity concentrations of carbon (C^{14}), potassium (K^{40}), polonium (Po^{210}), tritium (H^3), and radium (Ra^{226}) are approximately 63, 66, 133, 0.0002, and 2.7Ö10^{-5} Becquerels per kilogram (Bq/kg), respectively. The natural radioactivity detected in food typically ranges from $40Bq/kg$ to $600Bq/kg$[34]. For instance, (K^{40}) alone contributes around 420 Bq/kg in milk powder, 50 Bq/kg in milk, 125 Bq/kg in beef, and 165 Bq/kg in potatoes. Investigations on radioactivity in food, such as those by Mishra and Ramachandran, report that the concentration of K^{40} in various foods ranges from 45.9 Bq/kg to 649.0 Bq/kg, Ra^{226} from 0.01 to 1.16 Bq/kg, and Th^{228} from 0.02 Bq/kg to 1.26 Bq/kg[35].

To calculate the corresponding dosage in millisieverts per year (mSv/year), it is essential to consider not only energy and the fraction deposited in the body but also the radioactive and biological lifetimes of these isotopes within human body. When analyzing induced and natural radioactivity in food, it is essential to consider the elemental content of the food itself. The natural radioactivity of K^{40} isotope, which consistently constitutes 0.0117% of the K^{40} content in food, changes significantly depending on the potassium concentration in different foods.

Typically, potassium concentrations range from $1,000$ to $6,000$ parts per million (ppm). In a reference food, the potassium concentration was discovered to be 4000 ppm, but the usual concentration in a human's body is approximately 2000 ppm. Of the daily potassium consumption, about 90% is excreted through urine, and 10% through feces[36]. Additionally, the concentrations of several additional trace elements in food can also vary widely.

2.4|Radiation Protection

It's well-known that high dosages of ionizing radiation can harm human tissues. As scientists learned over the years, their concerns grew about the dangers of exposure to high amounts of radiation. To address these concerns and regulate radiation exposure, several expert groups were formed. In 1928, a group of independent specialists created the International X-ray & Radium Protection Committee (IXRPC), which ultimately evolved into the International Commission on Radiological Protection (ICRP)[37]. The ICRP's main role is to develop basic principles and make recommendations on how to protect people from radiation.

These guidelines and recommendations serve as the foundation for national regulations on radiation exposure for both workers and the general public. They've also been included in the Basic Safety Standards for Radiation Protection, published by the IAEA in collaboration with the OECD Nuclear Energy Agency (NEA), International Labour Organization (ILO), and World Health Organization (WHO)[38]. These standards are used globally to assure the protection and safety of people from radiation.

In 1955, the United Nations General Assembly formed the UNSCEAR. This committee's job is to gather, study, and share information about the levels of ionizing radiation and radioactivity in the environment, both from natural sources and human activities[39]. They also look into how this radiation affects people and the environment.

Radiation protection principles are pretty consistent worldwide. The ICRP advises that any radiation exposure beyond natural radiation background levels should be minimized as much as possible, while still staying below certain individual dose limits. For radiation workers, the limit is 100 mSv on average over 5 years, while for the general public, it's 1 mSv per year[40]. The limits are based on the idea that there's no safe threshold for radiation exposure—meaning any extra dose could increase the risk of health effects. However, this relationship hasn't been clearly proven for the lower doses where these limits apply.

There are some regions around the globe where natural background radiation is so high that people receive several times more radiation each year than the limit set for radiation workers. Because the number of people exposed in these areas is relatively small, it's hard to detect any potential health effects statistically. However, just because we haven't seen evidence of increased health problems doesn't mean that the risk is being ignored.

The IAEA and the ICRP advise that individual radiation exposure should be kept as low as possible. They also recommend taking into account other sources of radiation that might affect the same group of people. It's important to consider potential future sources or practices as well, to ensure that no one exceeds the set dose limits[41]. Typically, radiation workers receive much lower annual doses than the individual limits set for them. This shows that effective radiation protection practices can keep workers' exposure levels quite low.

2.5|Harmful Level of Radiation

The consequences of the radiation at high dosages and rates are fairly well understood. A relatively large dosage of radiation to the complete body in a short period can be fatal within days. Research on survivors of the Hiroshima and Nagasaki bombings has taught us that some health effects only show up after a significant dose. However, many other effects, like cancers, can be more noticeable and occur more frequently with modest doses. At lower dosages and slower rates, the body has a better chance to recover from radiation damage.

When it comes to lower dosages of radiation, there's still a lot of uncertainty about the overall consequences. It's believed that even natural background radiation might slightly increase the risk of cancer, but this hasn't been definitively proven. To accurately determine the risk at low doses through studies, we'd need to observe millions of people exposed to varying levels of radiation. This would be challenging, especially since we don't have a control group that's never been exposed to any radiation. Additionally, many everyday substances, like UV light, tobacco smoke, asbestos, certain chemical dyes, toxins in food, viruses, and even heat, can also cause cancer. Because of this, it's often impossible to pinpoint the exact cause of a specific cancer[42].

Animal studies have shown that radiation exposure can cause genetic effects, but studies on Hiroshima and Nagasaki survivors don't show this happening in humans. If low-level radiation were to cause hereditary effects in humans, detecting them would require analyzing large amounts of statistical data. This would be challenging, especially since many other factors could also cause genetic disorders, some of which only become apparent after the damage is done—thalidomide, given once to pregnant women as a sedative, is one example. The scientific debate on this issue will likely be resolved through advances in molecular biology rather than epidemiology. Despite all the knowledge we've gathered about the effects of radiation, we still can't say for sure whether natural background radiation poses a health risk, even though higher levels of exposure have been shown to be harmful.

2.6|Risks and The Benefits

Everyone encounters risks in everyday life. While we can't eliminate them entirely, we can work to reduce them. For instance, using coal, oil, or nuclear energy to produce electricity comes with some health risks, however small they may be. Generally, society accepts these risks because of the benefits they provide. Anyone exposed to cancer-causing pollutants faces some risk of developing cancer. The nuclear industry, in particular, makes significant efforts to minimize these risks as much as possible. Radiation protection specified a standard for other safety practices in two important ways:

- Firstly, it's assumed that any increase in radiation above the natural background levels carries some health risk.
- Secondly, it strives to protect the future generations from the consequences of today's activities.

The application of radiation and nuclear techniques in energy, industry, medicine, agriculture, and other disciplines has provided significant societal benefits. In medicine, radiation has been crucial for diagnosing and treating diseases, saving countless lives. It's especially important in treating certain types of cancer.

In fact, three out of four patients in industrialized countries benefit from some sort of nuclear medicine[43]. The positive impact of radiation extends to other fields as well. While no human activity is entirely risk-free, radiation should be seen as offering more benefits than many other agents, with fewer associated harms.

2.7|Assessment of Background Radiation Levels at Muree, Pakistan

Samples of soil were obtained from Murree and its surrounding areas to establish baseline data on natural and human-made radionuclides and their associated radiation doses. To measure the activity concentration, a High Purity Germanium (HPGe) spectrometry system was used. The concentrations of radionuclides—Ra-226, Th-232, K-40, and Cs-137—ranged between 20.0 to 29.5, 43.4 to 62.4, 163.0 to 493.6, and 1.3 to 54.1 Bq/kg, respectively.

The Ra-226 equivalent activity was between 107 and 148 Bq/kg, with an average of 128.0 Bq/kg. The average annual effective absorbed dosage was 72.9 ± 1.0 µSv/year, which is comparable to the global average. The radium equivalent activities, along with outdoor and indoor hazard indices, were all below the safety limits set by the OECD for the general public.

2.8|Maximum Work Environment Exposure

The Nuclear Regulatory Commission limits workplace radiation exposure to a maximum of 5,000 millirems per year. In contrast, firefighters who responded to the Chernobyl nuclear disaster were exposed to as much as 80,000 millirems. Tragically, 28 of these firefighters died within three days due to acute radiation syndrome.

2.9|Safe Levels of Exposure

The Nuclear Regulatory Commission limits public exposure to radiation from its licensees to no more than 100 millirems per year. At this level, people typically experience few, if any, negative effects. On average, the people around the world are exposed to about 2.4 mSv of background radiation each year, mostly from cosmic rays and naturally existing radioactive materials in their environment.

3|Experimental Techniques and Mathematical Formulation

We worked on the GM counter & tube. As we had to work on the effects of radiation in Sahiwal & to find out whether Sahiwal is safe from radiation or not. First of all, we decided a place from where data is collected. We decided on two different places in Sahiwal. Stepping into our first place, we placed the GM counter & tube for counting radiations. The GM counter, designed by H. Geiger and E.W. Muller in 1928, is a device that detects

Figure 6. Geiger-Muller (G.M) Counter.

radioactive particles. A standard GM counter includes a GM tube with a thin mica window, a high-voltage supply, a scalar to count the detected particles, and a timer to stop counting after a set period (shown in Fig-6).

The GM tube is highly sensitive, so even a particle that ionizes a single atom inside the tube will trigger a chain reaction of electrons and ions. This reaction creates a voltage pulse at the tube's output, which is strong enough to be recorded without much extra amplification. Although the pulse doesn't provide detailed information about the type of particle detected, the GM counter is versatile and can detect alpha, beta, and gamma rays. A gas counter comprises a chamber filled with an inert gas like argon at normal pressure, a central wire electrode, and a thin-end-window. It uses the ionizing effect of nuclear radiation to detect particles. The central electrode is positively charged (anode) and the chamber is negatively charged (cathode). When the voltage is applied, the gas becomes ionized: the positively charged ions move towards the chamber walls, while electrons head towards the anode. The device is set up to count these ionization events over a specific time period, and the ionization current is measured as counts per two minutes.

When we increased the voltage across the electrodes, initially there was no current until we reached the threshold voltage needed for ionization. Once this point was reached, the current began to rise slowly because the ions initially tend to recombine until a high enough voltage is applied. In this stage, negatively charged electrons move quickly toward the central anode, while the heavier positive ions move more slowly toward the cathode. Although the applied voltage is relatively low, this doesn't significantly affect measurements. In this region, known as the "saturation current region," output current stabilizes because all atoms interacting with the radioactive emissions become ionized.

The current produced reflects the rate at which charged ions are created. Of the three kinds of radiation— alpha, beta, and gamma—alpha particles are the most detectable in this region due to their large mass and charge, making this region particularly sensitive to them. Since the applied voltage is low, the current is also small and needs to be amplified to be accurately measured. The number of radiations coming inside the tube was noted down in a notebook and then, that data was assembled. Assembled data was then interpreted in the form of graphs by using normal distribution.

This PSoC design creates the high voltage needed to power the GM counter using a pulse transformer controlled by a PWM signal. The system regulates the voltage by adjusting the duty cycle of the PWM signal through a closed-loop control. The feedback circuit includes a sensing network, an integrator, a relaxation sawtooth oscillator, and a comparator. The design uses the PSoC's built-in switched capacitor user module (ASC and

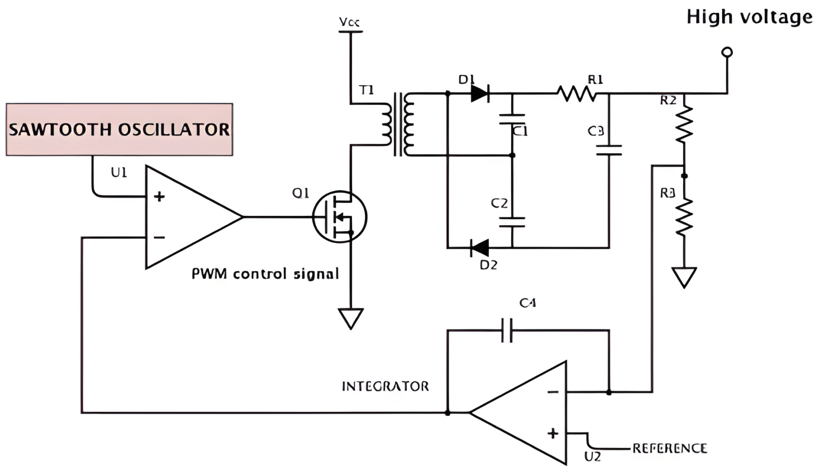

FIGURE 7. High voltage generation and feedback circuit in GM Counter.

ASD blocks) to manage the PWM duty cycle. Fig-7 provides a detailed description of how the high voltage is generated.

3.1|The Effective and Equivalent Dosage

The equivalent dose, $F(x_T, t)$, for an organ or tissue (x_T) is a key metric used in radiation protection to calculate the whole-body effective dose, as outlined by the ICRP [44]. This dose is determined by multiplying the mean absorbed dose in the organ or tissue by the relevant radiation weighting factors $D_R(x_T, t)$. The equivalent dose is calculated by summing the absorbed doses from all types of radiation impacting the organ or tissue, each adjusted by its specific radiation weighting factor (W_R):

$$F(x_T, t) = \sum_R W_R D_R(x_T, t)$$

Effective dose is a calculated metric used in radiation protection to estimate the risk associated with radiation exposure. It serves as the basis for determining annual radiation limits for workers and the general public, as well as for comparing recorded occupational doses to established radiation protection standards. Rather than representing an actual dose received by an individual, the effective dose is a theoretical value that approximates the stochastic risk of radiation, applied to a representative model[45].

$$E = \sum_T W_T \left[\frac{F_R(x_T, t)^{male} + F_R(x_T, t)^{female}}{2} \right]$$

3.2|The Normal Distribution Technique

The normal distribution technique is among the most significant and widely used distributions in statistics. It's often referred to as the "bell curve" because of its shape, even though it might not make for a very melodious bell! It's also known as the Gaussian curve, named after the mathematician Karl Friedrich Gauss. This distribution was first discovered by Abraham de Moivre.

Technically, it's not accurate to refer to the normal distribution as there are actually multiple normal distributions, each differing in the means and standard deviations (SD). For example, the Fig-8 depicts three different normal distributions: the green one (on the left) has a mean of negative three and an SD of half, the red one (middle) has a mean of zero and an SD of one, and the black one (on the right) has a mean of two and an SD of three. All normal distributions are symmetric, with more values clustered around the center and fewer values in the tails.

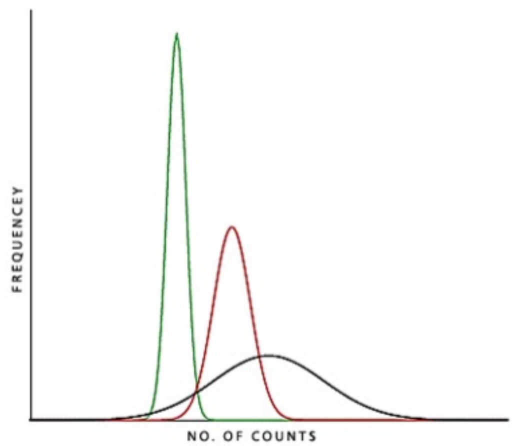

Figure 8. Illustration of Normal distributions differs in mean and SD.

Many things in life follow a normal distribution or are close to it. For example, human height and IQ are roughly normally distributed, and measurement errors often follow a normal distribution too. This distribution is mathematically convenient to work with, and methods based on it often perform well even when the actual distribution isn't normal.

There's a strong link between sample size (N) and how closely a sampling distribution approximates this distribution. Even if the population distribution itself isn't normal, sampling distributions with a large N can often be approximated by this distribution. The formula for this distribution is written as:

$$g(x;\mu,\sigma^2) = \frac{e^{-\frac{(x-\mu)^2}{2\sigma^2}}}{\sqrt{2\pi\sigma^2}}$$

In a normal distribution, the parameters μ and σ represent the mean and SD, respectively. The symbol e stands for the base of the natural logarithm.

Here are seven key features of normal distributions:

- They are symmetric around their mean.
- The median, mean, and mode are all the same.
- The total area under the curve equals one.
- They have higher density in the center and lower density in the tails.
- They are characterized by two parameters: the mean (μ) and the SD (σ).
- About 68% of the values fall within one SD of the mean.
- Approximately 95% of the values fall within two SD of the mean.

4|Results and Discussions

Humans are constantly exposed to the background radiation from radioactive materials found in the atmosphere, soil, rocks, water, and construction materials. The level of this radiation can vary depending on factors like elevation, the concentration of the radioactive materials in the soil, and the specific geographical conditions of different areas. Radioactive elements are commonly present in rocks, soil, beach sand, river sediments, and even in construction materials.

The concentration of these radioactive isotopes in soil can reflect the level of radiation in the environment, which affects humans, animals, and plants. Many of these isotopes have significantly long half-lives, often lasting

hundreds of millions of years. Additionally, the presence of certain radionuclides, like thorium and uranium, in the soil can influence the background radiation dosage in a given area.

4.1|Data Collection and Image Segmentation

The data will likely exhibit a bell curve distribution due to the strategic selection of locations, which vary significantly in their exposure to radiation. For instance, one of our selected sites is a modern experimental lab housing various radiation sources, while the other is a densely populated area near a coal power plant, with high foot traffic and vehicular activity.

A sample for the number of radiations coming inside the tube is shown in the form of the Table-2 below for two different locations for the next twenty days on each location and then, that data was assembled. First, we collected the data at the Modern Physics lab of Govt. Postgraduate College, Sahiwal (GPGCS), and at College Chowk, Sahiwal. Then the complete data was assembled using the technique described above, then interpreted in the form of graphs (Fig-9,10,11,12) as shown below for the different locations.

A normal distribution, or bell curve, is critical in statistical sampling because it reflects the expected distribution of characteristics within a population. This type of distribution is particularly valuable for predicting process variability and understanding the extent of natural variations in a given process.

$$g(x;\mu,\sigma^2) = \frac{e^{-\frac{(x-\mu)^2}{2\sigma^2}}}{\sqrt{2\pi\sigma^2}}$$

Table 2. Radiation count at the modern lab of GPGCS

No. of Observations	No. of Counts	No. of Observations	No. of Counts
1	52	16	63
2	53	17	66
3	47	18	67
4	65	19	53
5	61	20	63
6	61	21	47
7	48	22	55
8	58	23	61
9	50	24	59
10	55	25	70
11	68	26	59
12	62	27	59
13	71	28	45
14	56	29	62
15	64	30	52

In a standard normal distribution, approximately 68.2% of the data falls within one SD of the mean, 95.4% within two SD, and 99.7% within three SD. It's important to note that the tails of the distribution are asymptotic, meaning they approach but never quite reach zero, which is why the total does not sum to 100. The calculated normalization value with the above formula is given below in the Table-3.

First of all, we find the mean of the above data which is 58.4 then we find the variance of this data which is 47.97 by using the formula; Variance = Deviation about mean / (No. of observation-1). After that, we find the SD of table 2 which is 6.92 by using the formula; $SD = \sqrt{Vaience}$. Now by using the value of mean, variance, and standard deviation in the following formula of Normal distribution we normalize the data and plot a graph between No. of counts and frequency (Normalized value) shown in Fig-13 and Fig-14 and then the total radiation curve for the forty days at Sahiwal in Fig-15.

Table 3. Radiation count at the modern lab of GPGCS

No. of Counts	Normalization Value	No. of Counts	Normalization Value
52	0.00063986	63	0.05759836
53	0.001142815	66	0.056457836
47	0.001961078	67	0.053169988
65	0.00323327	53	0.048110194
61	0.005121739	63	0.041824994
61	0.00779509	47	0.034935171
48	0.011398641	55	0.028036132
58	0.016014493	61	0.021617304
50	0.021617304	59	0.016014493
55	0.028036132	70	0.011398641
68	0.034935171	59	0.00779509
62	0.041824994	59	0.005121739
71	0.048110194	45	0.00323327
56	0.053169988	62	0.001961078
64	0.056457836	52	0.001142815

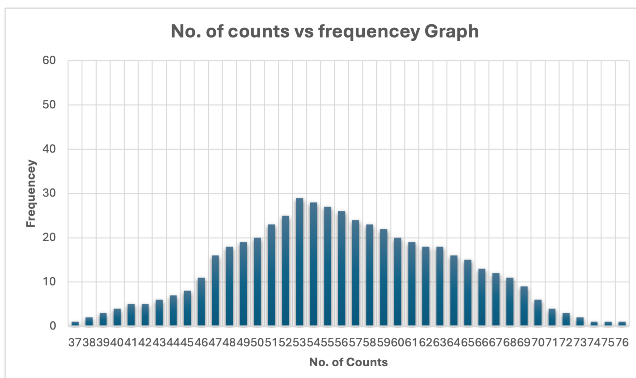

Figure 9. Radiation count at Modern Physics lab of Govt. Postgraduate College, Sahiwal for twenty days.

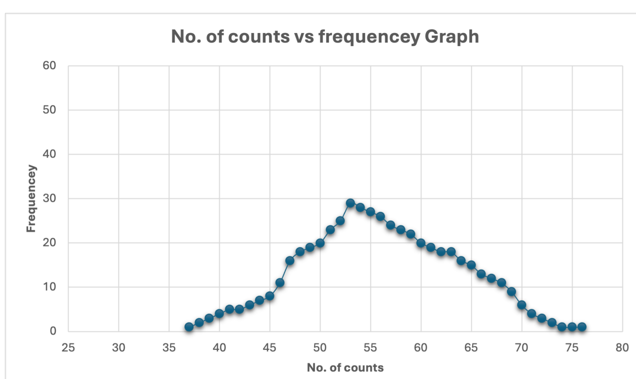

Figure 10. Radiation count at Modern Physics lab of Govt. Postgraduate College, Sahiwal for twenty days.

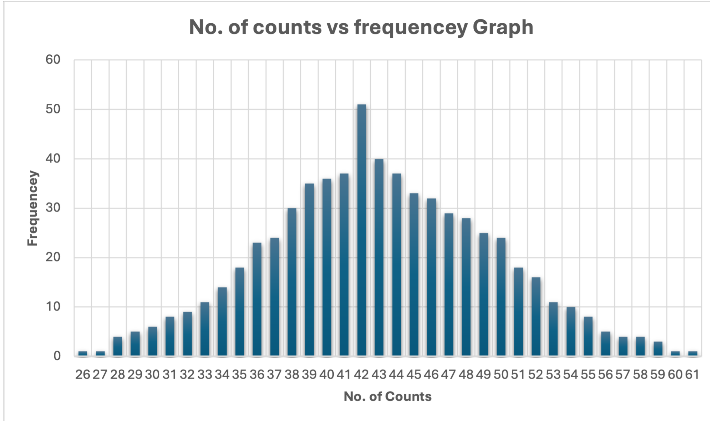

FIGURE 11. Radiation count at College Chowk, Sahiwal for twenty days.

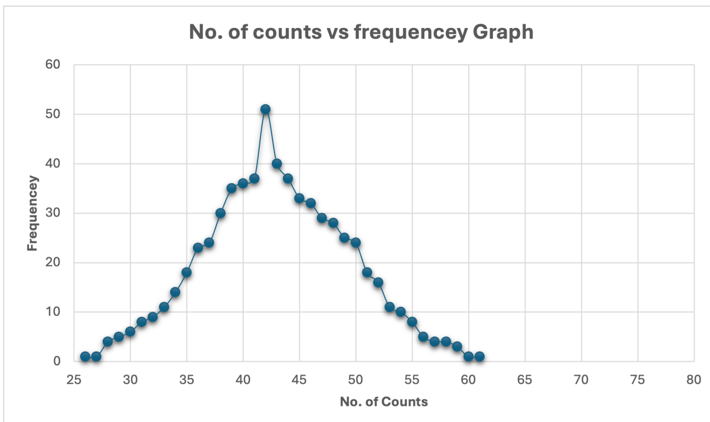

FIGURE 12. Radiation count at College Chowk, Sahiwal for twenty days.

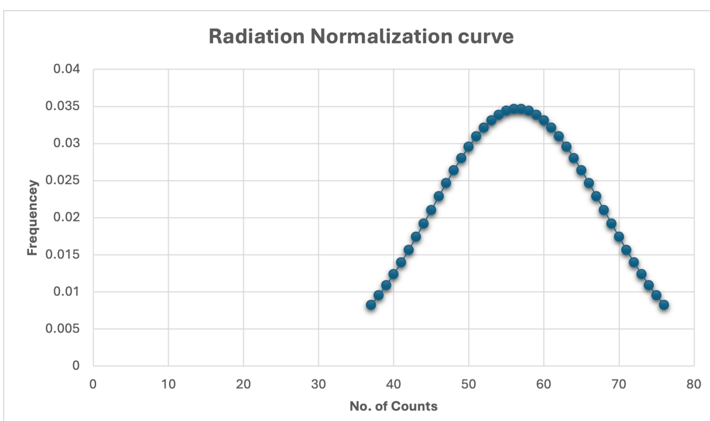

FIGURE 13. Radiation Normalization Curve for the counts at Modern Physics lab of Govt. Postgraduate College, Sahiwal for twenty days.

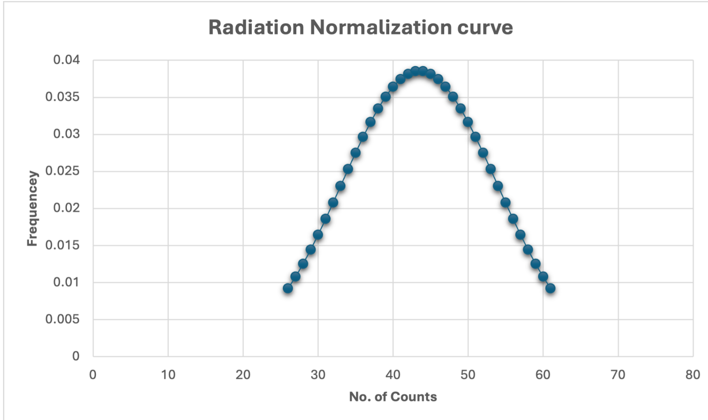

FIGURE 14. Radiation Normalization Curve for the counts at College Chowk, Sahiwal for twenty days.

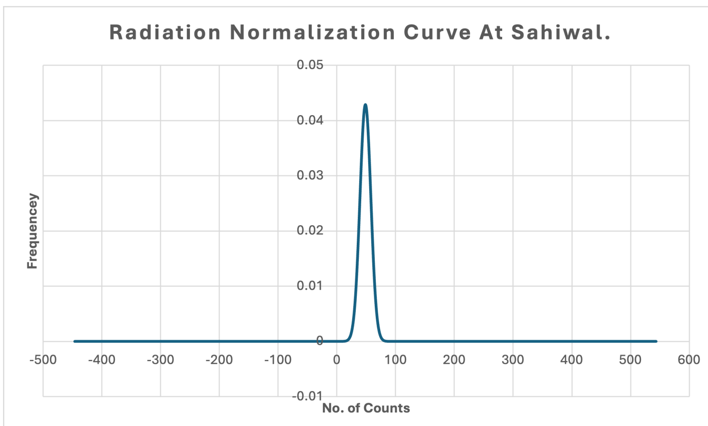

FIGURE 15. Radiation Normalization Curve for the counts at Sahiwal for forty days.

4.2|Calculated Exposure Level

We find the mean of the above mentioned collected data which is 48.45 Bq for each 2 min count. The radiation activity per second is 0.404 Bq. The portion of cosmic rays in the background radiation is 0.4 % other than this all the radiations are the background radiation. The portion of cosmic rays in B.R $0.0016Bq$. Cosmic rays consist on 89 % protons, 9 % Alpha-particles, 2 % Beta-particles. Now we have to calculate the background radiations by subtracting the cosmic rays from total radiations, which is $0.4024Bq$. From the above formula the calculated background radiations are $0.4024Bq/second$.

The total energy for the mean of total background radiation $48.45Bq$ is the $55.249Mev$ and if we convert in joules it will be $8.85 \times 10^{-12}J$ and in terms of miliSievert is $0.27mSv/year$. From the above calculation in Sahiwal the effective absorbed dosage of ionizing radiation in the human tissue is may be equal to $0.27mSv/year$ which is very low according to the international level of effective absorbed dosage of ionizing radiation in human tissue.

Now we divide the total background radiations in the same proportion of the cosmic rays into 9% Alpha ($4.3605Bq$), 2% Beta ($0.969Bq$) and 89 % gamma ($43.12Bq$) and their calculated energy as $32.70Mev$, $0.989Mev$ and $21.56Mev$ respectively. For some of the higher counts we got, the proportion of α,β,γ and their energies in Mev are given in the Table-4.

The risk estimates were derived by considering the typical doses absorbed by various organs and tissues, along with age and sex specific risk factors for different types of cancer. Additionally, the effective dose for each

TABLE 4. The proportion of α,β,γ and their energies in Mev for some higher counts

No. of Counts	α	β	γ	Total Energy (MeV)
81	7.29	1.62	72.09	93.16
79	7.11	1.58	70.31	90.86
76	6.84	1.52	67.64	87.41
73	6.57	1.46	64.97	85.31
71	6.39	1.42	63.13	81.66
70	6.30	1.39	62.31	80.58

procedure was calculated to allow for comparison of the risk per unit of effective dose (measured in sieverts, Sv). Fig-16 illustrates the findings of [46], who used risk data from an ICRP Euro-American (EA) composite population. This analysis incorporates data from three EA and four Asian populations .

$$E = \sum_T W_T \left[\frac{F_R(x_T,t)^{male} + F_R(x_T,t)^{female}}{2} \right]$$

The study shows that while the lifetime risk of radiation-induced cancer generally decreases with patient age across all types of examinations, the rate and pattern of this decline vary significantly between different types of examinations and between genders. These variations are due to differences in how the radiosensitivity of various organs and tissues changes with age and sex.

4.3|Internationally Safe Level Of Background Radiations

The Nuclear Regulatory Commission limits public exposure to radiation from its licensees to no more than 100 millirems per year. At this level, people generally experience few health effects. On average, people around the world receive about 2.4 millisieverts (mSv) of background radiation each year, primarily from cosmic rays and natural radioactive materials in the environment. In contrast, the Commission allows a maximum of five thousand millirems of exposure per year in occupational settings. Firefighters who responded to the Chernobyl nuclear disaster, however, were exposed to up to 80,000 millirems, and tragically, 28 of them died from acute radiation syndrome within three days.

4.4|Biological Effects

Exposure to ionizing radiation can have harmful consequences on the human body. The extent and severity of these effects mainly depend on how much radiation is absorbed and how quickly it is received. Radiation exposure can lead to issues like burns, cancer, radiation sickness, genetic disorders, and deformities in unborn offspring. Extremely high dosages of radiation to the entire body can be fatal. These harmful consequences have been reported in various situations, including medical treatments with X-rays, radiation accidents, and among survivors of the atomic bombs in Japan.

4.4.1|Radiations Burn

Radiation burns happen when a high amount of radiation hits a tiny area of the human body. These burns were first observed shortly after X-rays were discovered by Roentgen. By a year, it became clear that radiation workers needed to take precautionary actions to prevent these injuries. A dose of about 300 rem is the minimum needed to cause visible skin damage, such as reddening known as erythema, which can appear two to three weeks after exposure in very sensitive individuals. Typically, a dose over six hundred rem is required before radiation burns are noticeable. These burns are similar to first-degree thermal burns, like a moderate sunburn. Initially, there might be no symptoms, and the person may not even realize they've been injured. However, such injuries are generally rare in radioisotope labs.

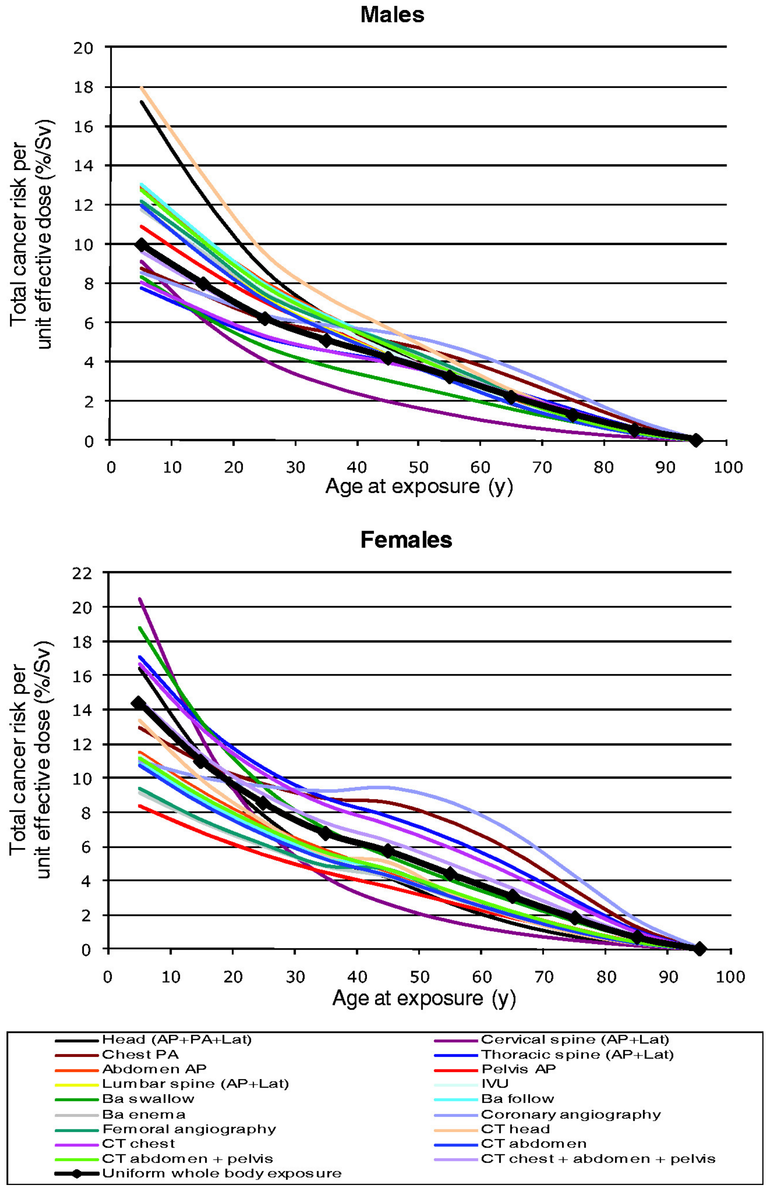

FIGURE 16. The total life-time cancer risk per unit of effective dosage for the ICRPEA composite population, shown as the function of the age at which exposure occurs.

4.4.2|Radiation Sickness

To show noticeable symptoms, radiation doses over 100 rem to the whole body are usually required if delivered within a few hours. However, changes in blood can be detected with doses as low as twenty-five rem. Symptoms typically appear within a few hours to days, based on the dosage. The initial stage of radiation sickness often includes nausea, diarrhea, and vomiting. After this, symptoms might ease and the person may feel better, a period that can last from hours to weeks, even though internal changes continue.

Depending on the dose, symptoms can progress to hair loss, loss of appetite, exhaustion, fever, vomiting, severe diarrhea, internal bleeding, and potentially death. For doses between 400-500 rem, about 50% of people exposed would die within thirty days without treatment. With medical care, recovery is possible but can involve many months of illness. If the dosage is spaced out over some weeks, a person might survive doses as high as 1000 to 2000 rem[47]. However, exposure to over 700 rem in a short time is likely to be fatal within a few weeks, as it damages the bone marrow and prevents the production of enough red blood cells.

4.4.3|Genetic Effect

Exposure to radiation can affect reproductive cells, potentially causing genetic damage that may be passed on to future generations. However, studies of children born to survivors of the Hiroshima and Nagasaki bombings have not shown an increase in genetic defects beyond what would be expected. Identifying specific genetic defects can be challenging because there are often no immediate signs, and it may take several generations or large populations before a mutation becomes noticeable. Radiation is a strong mutagenic agent, and even small amounts can potentially harm reproductive cells. The probability of a genetic flaw in a child of someone exposed to just one rem of radiation is roughly one-third that of the risk of developing cancer from the same exposure, translating to about a one in 10,000 chance.[48] Since genetic defects are less common and less severe than cancer, the cancer risk from the radiation exposure is considered much significant.

4.4.4|Teratogenic Effectst

Exposure to radiation during pregnancy can be harmful to the unborn child. This is known as teratogenic effects, which involve malformations occurring during the early stages of development. Evidence from studies on Japanese bomb survivors and the children who were exposed to diagnostic X-rays in the womb has shown increased risks. For example, children of A-bomb survivors had higher rates of mental retardation and smaller head sizes. Exposure to diagnostic X-rays during pregnancy, especially in the first trimester, has been linked to a greater incidence of leukemia in children. Given the developing fetus's sensitivity to radiation, pregnant workers should limit their total radiation exposure to 500 rem throughout the pregnancy to minimize risks[49].

4.4.5|Cancer

Ionizing radiation is known to be a cancer-causing agent in both animals and humans, and it's been linked to all types of human cancers. The cancers most strongly associated with radiation exposure including leukemia, and cancers of the lung, breast, bone, liver, thyroid, and skin. By 1905, it was already well understood that radiation might cause the cancer. Many early researchers who worked with large amounts of radiation repeatedly, such as Marie and Pierre Curie, suffered from fatal conditions like leukemia and skin cancer. Marie and Pierre Curie, in particular, both developed the leukemia, likely due to their work with radium.

There is more evidence showing that ionizing radiation can cause cancer in humans in various situations. For instance, radiation workers, children exposed to diagnostic X-rays before birth, patients who receive therapeutic X-rays or internal radiation, people exposed to fallout, and survivors of the atomic bombings in Japan all have shown higher cancer rates linked to radiation exposure. Specifically, there's been an increase in cancer cases among those who had diagnostic X-rays, and children who were exposed to radiation from abdominal X-rays given to their mothers during pregnancy have shown higher rates of leukemia. An increase in breast cancer cases has been observed among women who had frequent fluoroscopic exams while being treated for tuberculosis. Similarly, patients who received therapeutic X-rays for conditions like scalp ringworms, spinal arthritis, and enlarged thymus glands also showed higher cancer rates. For example, infants who were treated to reduce thymus gland size often received radiation doses ranging from 120 to 6,000 rad, which has been linked to higher rates of thyroid cancer and leukemia.

About twenty-five percent of adults between the age group of twenty and sixty-five will develop cancer at some point in their lives. While the exact risk of developing cancer from ionizing radiation exposure for an individual is not fully known, risk estimates can be generated using statistical data from populations exposed to high levels of radiation. In a 1990, paper called "Health Effects of Exposures to Low Levels of Ionizing Radiation - BEIR-V", the National Research Council (NRC) estimated that a single exposure of ten rem would increase the lifetime risk of dying from cancer by 0.8%. This means that if a thousand people each received a 10 rem dose, we would expect about 8 of them to die from cancer caused by the radiation. This is in addition to the roughly 220 cancer deaths that would occur from other causes[50].

4.5|Comparison with Other Cities

In this section, we compare the value of the effective absorbed dose of ionizing radiation in human tissue in Sahiwal with some other places of the world.

4.5.1|At Sahiwal, Pakistan

In Sahiwal, the effective absorbed dosage of ionizing radiation in the human tissue for the 8.85×10^{-12} J energy is equivalent to 0.27 mSv/year.

4.5.2|At Kerala, India

The Worldwide average of the effective dosage from the natural background radiation is around 2.4 mSv/year. In the Kerala coast, this is about 12.5 mSv/year. The composition of population exposure in India across all recognized sources. The total collective dose for the Indian population is 2490 μSv/year to the current Indian population. [51]

4.5.3|At United Kingdom (UK)

The value of the effective absorbed dosage of the ionizing radiation in human tissue for the population of the United Kingdom is 2200 μSv per year. [52]

4.5.4|At United States of America (USA)

The value of the effective absorbed dosage of the ionizing radiation in human tissue for the population of the USA is 2950 μSv per year. [53]

4.5.5|At Japan

The value of the effective absorbed dosage of the ionizing radiation in human tissue for the population of Japan is 1644 μSv per year. [54]

5|Conclusion

Humans are continuously exposed to the background-radiation originating from naturally occurring radioactive nucleies in the atmosphere, rocks, soil, water, and even in construction materials. While we can't eliminate them entirely, but we can work to reduce them. To assess how these radiation levels might change over time, scientists employ long-term monitoring and predictive modeling. These efforts are essential for understanding the potential impacts of climate change, geological processes, and human activities on background radiation levels. This paper formulated a comprehensive measurement of background radiations in the Sahiwal with the help of Geiger-Muller Counter.

The consequences of the radiation at high dosages and rates are fairly well understood. On average, people around the world receive about 2.4 millisieverts (mSv) of background radiation each year. This radiation mainly comes from cosmic rays and natural radioactive materials in our environment. But in Sahiwal, the effective absorbed dosage of ionizing radiation in the human tissue for the 8.85×10^{-12} J energy is equivalent to 0.27 mSv/year.

So, according to the internationally safe level for the effective absorbed dosage of ionizing radiation in the human tissue and from the calculations, we conclude that Sahiwal is a safe city for living of human beings according to the international level of background radiation exposure. However, just because we haven't seen evidence of increased health problems doesn't mean that the risk is being ignored.

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